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Factors Affecting Growth Pattern and Condition of *Butis koilomatodon* (Bleeker, 1849) (Gobiiformes: Eleotridae) from the Mekong Delta, Vietnam

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Abstract: The study aimed to provide information on growth patterns and condition factors affecting the eleotrid fish *Butis koilomatodon* from the Mekong Delta, Vietnam, as depending on gender, season and sites. Totally, 1,063 fish specimens (768 males and 295 females) were collected from January to December 2019 along the mudflat and mangroves in the Tra Vinh, Soc Trang, Bac Lieu and Ca Mau Provinces. The weight and total length of this species were significantly different between genders, seasons and sites. The length-weight relationship was positive, being affected by gender, season and study area. The change in growth patterns (negative and positive allometry and isometry) depended on the season and the region since the slope (*b*) fluctuated from 1.89±0.17 to 3.33±0.10. This species was generally characterised by a negative allometric growth, as *b* (2.66) was significantly lower than the isometric threshold. The conditional factor of *B. koilomatodon* was close to the well-being value and was not impacted by gender but depended on season and site variables. These results showed that the species was well-adapted to the habitat and to the dry season.

Key words: Butinae, seasonal growth differences, spatial growth differences, negative allometric growth

Introduction

Butis koilomatodon (Bleeker, 1849) is an eleotrid species occurring in the coastal regions and estuaries throughout the Indo-Pacific Ocean between China, Philippines, Australia and Madagascar (Miller et al. 1989). The distribution of the species is from freshwater to brackish, ranging from East Africa to Fiji (McDowall 1997, Froese & Pauly 2019). The annual fish yield in downstream of the Mekong River Basin is c. 2 million tons (Hortle 2009) and, in 2019, it has reached 3.2 million tons (Kieu Linh 2019). Among other species, *Butis* spp. played an essential role in the total fisheries production in the

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Mekong Delta, with their life cycle and distribution depending on the ecosystem of the Mekong River (Poulsen et al. 2002). Many groups of goby-related fishes lay eggs and complete their life cycles in the lower Mekong River (Blaber 2008).

In Vietnam, five species of the genus *Butis* have been recorded: *B. butis* (Hamilton, 1822), *B. amboinensis* (Bleeker, 1853), *B. gymnopomus* (Bleeker, 1853), *B. koilomatodon* and *B. humeralis* (Valenciennes, 1837) (Tran et al. 2013). Amongst them, *B.koilomatodon* is a commercially valuable species, especially in coastal estuaries from Duyen Hai (Tra Vinh Province) to Cu Lao Dung, Tran De (Soc Trang Province), Hoa Binh, Dong Hai (Bac Lieu Province) and Dam Doi (Ca Mau Province). So far, this mud sleeper goby has been caught in natural habitats mainly and is facing overexploitation (Trinh & Tran 2012), which seriously plunged the yield of this species.

Understanding the relationship between length and weight (LWR) of the species is a necessary tool for evaluating fish population and estimating fish length and weight (Khaironizam & Norma-Rashid 2002, Mahmood et al. 2012, Dinh et al. 2016). The data were used to get the regression coefficient value (*b*), which brings useful information for estimating fish growth patterns (Froese 2006). The factor affecting the condition (CF) is a valuable indicator for comparison of fish well-being between regions, seasons and genders (Abdoli et al. 2009a, 2009b). However, data of the growth pattern and condition factor varies between fish sizes and seasons as well as between males and females. With little and fragmented data, this study was set to provide more precise information on the growth and adaptation of *B. koilomatodon* in the Mekong Delta. Furthermore, the data are to be added to the database of the local fish for the estuaries of the Mekong Delta in order to be used as a baseline record for the purposes of further studies.

Materials and Methods

Study site and fish collection

This study was carried out at six sites along the coastline: Long Huu, Duyen Hai, Tra Vinh (LH, 9°41’18.6”N 106°30’35.8”E); An Thanh 3, Cu Lao Dung, Soc Trang (AT3, 9°33’20.1”N 106°16’57.9”E); Trung Binh, Tran De, Soc Trang (TB, 9°29’26.8”N 106°11’58.5”E); Vinh Hau, Hoa Binh, Bac Lieu (VH, 9°12’24.8”N 105°42’54.9”E); Dien Hai, Dong Hai, Bac Lieu (DH, 9°06’03.2”N 105°29’49.1”E); Tan Thuan, Dam Doi, Ca Mau (TT, 8°58’17.5”N 105°22’51.8”E) (Fig. 1). These sites are bordered with large areas of *Avicennia marina* and *Sonneratia caseolaris* mangroves and are characterised by a large mudflat area and semi-diurnal tide. Specifically, these districts are deemed to be susceptible to the natural processes including saline intrusion, alluvial, sedimentation, storm surges, inundation, soil degradation and, especially, coastal erosion (Thanh et al. 2013). Using the permitted fishing tools, cod-end, with nine deep gill nets of 1.5 cm mesh size, the samples were collected monthly from January to December 2019. At each of the collection sites, three gill nets were set up when the tide was highest. After 2-3 hours when the tide ebbed, the fishes were collected following the method described by Dinh et al. (2015). Finally, the collected fish samples were preserved in 5% formalin and transported to the laboratory for identification using external morphology as described in Tran et al. (2013).

The weather in the South of Vietnam is affected by the tropical monsoon and equatorial climate, with the mean annual temperature of ~27^{o}C (Le et al. 2006). Because of the tropical monsoon and the equatorial climate, two seasons are formed, i.e. dry season (January – May) and wet season (June – December). The rainfall has been measured at 400 mm per month in June – September.

Fish analysis

In the laboratory, fish specimens were measured with the nearest of 0.1 cm in total length (TL) and weighted (W) with the nearest of 0.01 g in body weight (W). We identified the sexes by the shape of the urogenital papilla, which is broad and square in females, and narrow and pointed in males.

Data analysis

The relationship between TL and W values was estimated by the following formulas (Ricker 1973):

$$W = a \times TL^{b}$$

(W is fish body weight (g), TL is fish total length (cm), *a* is the regression intercept, *b* is the regression slope). Using the function of Le Cren (1951), the fish body condition factor was determined:

$$CF = \frac{W}{a \times TL^{b}}$$

where W is fish body weight (g), TL is fish total length (cm), *a* is the regression intercept and *b* is the slope. Parameters *a* and *b* were inferred from the formula LogW = log*a* + *b*×LogTL (Froese 2006).

To examine the differences in TL and W between genders and seasons, the t-test was used. One-way ANOVA was used to test the variation of

Table 1. Variations of growth pattern and condition factor of female and male *Butis koilomatodon* during the dry and wet seasons

Fish groups		No. of fish TL	Range W	Range TL	Mean±SE W	Mean±SE Mean± SE	b Mean± SE	a	r²	t_s	Growth type Mean± SE	CF
Gender	Male	768	6.71-7.93	4.07-7.45	7.35±0.04^{a}	6.01±0.09^{a}	2.71±0.05	0.026±0.003	0.786	-5.80	N	1.02±0.01^{a}
	Female	295	5.79-7.25	3.23-5.96	6.54±0.05^{b}	4.44±0.11^{b}	2.58±0.08	0.033±0.005	0.775	-5.25	N	1.03±0.01^{a}
Season	Dry	461	5.79-7.89	3.23-6.91	7.39±0.05^{a}	6.05±0.13^{a}	2.97±0.04^{b}	0.015±0.001	0.924	-0.75	I	0.98±0.01^{b}
	Wet	602	5.93-7.93	3.59-7.45	6.92±0.04^{b}	5.21±0.09^{b}	2.45±0.06^{a}	0.043±0.006	0.695	-9.17	N	1.05±0.02^{a}
Study area	Long Huu, Duyen Hai, Tra Vinh	90	5.70-9.70	2.22-13.05	7.73±0.09^{a}	6.92±0.28^{a}	3.33±0.10^{d}	0.001±0.001	0.926	3.30	P	1.01±0.02^{d}
	An Thanh 3, Cu Lao Dung, Soc Trang	110	4.00-11.10	0.91-16.05	6.91±0.12^{b}	4.93±0.25^{d}	2.96±0.06^{c}	0.015±0.002	0.956	-0.67	I	0.94±0.01^{c}
	Trung Binh, Tran De, Soc Trang	66	4.30-9.00	0.93-10.25	6.71±0.14^{b}	4.12±0.26^{cd}	3.01±0.09^{c}	0.012±0.002	0.943	0.11	I	0.85±0.01^{c}
	Vinh Hau, Hoa Binh, Bac Lieu	351	4.80-10.20	2.07-16.66	7.41±0.05^{a}	6.09±0.13^{ab}	2.72±0.06^{b}	0.025±0.003	0.844	-4.67	N	1.01±0.01^{b}
	Dien Hai, Dong Hai, Bac Lieu	216	2.90-9.50	1.76-14.01	6.96±0.07^{b}	5.12±0.15^{c}	2.64±0.09^{b}	0.028±0.005	0.802	-4.00	N	1.01±0.03^{b}
	Tan Thuan, Dam Doi, Ca Mau	230	4.90-9.40	2.12-13.07	6.83±0.06^{b}	5.41±0.14^{bc}	1.97±0.12^{a}	0.118±0.026	0.556	-8.58	N	1.16±0.02^{a}
Total		1,063	1.05-48.20	4.90-15.80	9.33±0.08	9.73±0.30	2.66±0.04	0.028±0.002	0.801	-8.50	N	1.02±0.01

Note: Different letters in each category showed a significant difference

TL and W amongst the six sites. The influence of gender and season causing changes on TLs and Ws was tested by two-way ANOVA. The determination coefficient (r^2) was used to confirm the quality of linear regression (Metin et al. 2011). The *b* value obtained from the LWRs of *B. koilomatodon* depending on genders and seasons was quantified by t-test. After that, the *b* value was assessed if it was higher than 3, if so, it means the growth type is positive allometry. Contrary, the growth was negative allometry (b<3) and isometric if b=3 (Martin 1949). The variation of *CF* value, between months and sites, was confirmed by one-way ANOVA, and the change of *CF* between gender and season was approved by t-test (Mahmood et al. 2012). The interactions of gender × season, gender × site, and season × site influenced *b* and *CF*, were tested by using two-way ANOVA based on the method of Dinh (2016a).

Additionally, the t-test was used to verify the significant differences of *CF* from the favourable condition. The SPSS software, v. 21, was applied for data analysis. All tests were set at p<0.05.

Results

Morphometrics

A total of 1,063 *B.koilomatodon* (768 males and 295 females) specimens were collected at six sites from January to December 2019, as shown in Table 1. The average value of TLs and Ws were different between male (7.35±0.04 cm and 6.01±0.09 g) female (6.54±0.05 cm and 4.44±0.11 g) at significant level of 5% (t-test, t_{TLs}=12.73, t_{Ws}=10.93, p<0.01, Table 1). Regarding the seasons, the result was a statistical difference for the mean of TLs and Ws amongst dry season (7.39±0.05 cm and 6.05±0.13 g) and wet season (6.92±0.04 cm and 5.21±0.09 g, t_{TLs}=7.45, t_{Ws}=5.46, p<0.01, Table 1). Table 1 also revealed that sampling sites also affected the variation of TLs and Ws (one-way ANOVA, F_{TLs}=20.20, F_{Ws}=17.74, p<0.01, Table 1). Means of TLs and Ws were highest in LH (7.73 cm and 6.92 g) and VH (7.41 cm and 6.09 g, lowest in AT3 (6.91 cm and 4.93 g) and TB (6.71 cm and 4.12 g). The average of TLs and Ws were 6.96 and 5.12 g in DH, and 6.83 cm and 5.41 g in TT.

The TLs and Ws were independent on the interactions of the gender × season (two-way ANOVA, F_{TL}=0.15, and F_W=0.06, p>0.05) and gender × site (ANOVA, F_{TL}=1.14 and F_W=1.23, p>0.05). However, they were affected by the interaction between season and site (ANOVA, F_{TL}=5.214 and F_W=5.755, p<0.05).

Table 2. Monthly variations of growth pattern and condition factor of *Butis koilomatodon*

Sampling times	Number of fish	b	a	r^2	t_s	Growth pattern	CF
		Mean± SE	Mean± SE				Mean±SE
January	89	2.97±0.14	0.014±0.004	0.844	-0.21	I	$0.96±0.01^{b}$
February	41	3.25±0.16	0.009±0.003	0.914	1.56	P	$1.00±0.02^{a,b}$
March	42	2.90±0.15	0.016±0.005	0.910	-0.67	I	$0.94±0.02^{b}$
April	110	2.93±0.12	0.017±0.004	0.846	-0.58	I	$1.04±0.02^{a,b}$
May	113	1.89±0.17	0.132±0.044	0.530	-6.53	N	$1.09±0.03^{a,b}$
Jun	107	1.94±0.20	0.118±0.044	0.473	-5.3	N	$1.15±0.04^{a}$
July	93	2.03±0.17	0.088±0.029	0.599	-5.71	N	$1.02±0.08^{a,b}$
August	100	3.01±0.08	0.014±0.002	0.928	0.13	I	$0.98±0.01^{b}$
September	91	3.24±0.11	0.009±0.002	0.908	2.18	P	$1.04±0.01^{a,b}$
October	98	2.78±0.17	0.022±0.007	0.736	-1.29	N	$1.03±0.04^{a,b}$
November	86	3.06±0.08	0.012±0.002	0.943	0.75	I	$0.98±0.01^{b}$
December	93	2.89±0.05	0.017±.002	0.976	-2.2	I	$0.96±0.01^{b}$
Total	1,063	2.66±0.04	0.028±0.002	0.801	-8.5	N	1.02±0.01

Note: Different letters showed a significant difference in condition factor (*CF*)

Length-weight relationship and growth pattern

Fish total length at different sizes could be used to infer weight under the various conditions such as gender, season and site because coefficients of LWRs are relatively high ($p<0.001$, $r^2>0.8$ for all cases, except for r^2 value in June–July (Tables 1 and 2).

The growth pattern identification was based on the *b* value. The slope values (*b*) of females and males were 2.58 and 2.71, respectively. Both of the growth patterns were negative allometry due to their *b* values were lower than three – the isometric value (t-test, t_{female}=31.80, t_{male}=53.04, $p<0.01$, Table 1). On the contrary, *b* value of dry season (2.97) was approximately threshold three (t=74.49, $p<0.01$, Table 1), whereas this value in the wet season (2.45) was lower than three (*t*=36.94, $p<0.01$, Table 1). Basing on *b* values, the growth model of *B.koilomatodon* in the dry season was isometric and wet season was negative allometry. The *b* values of this species in TT (1.97), DH (2.64) and VH (2.72) were lower than three (t_{TT} =16.89, t_{DH} =29.43, t_{VH}=43.44, $p<0.01$, Table 1), yet this value was closed to three in TB (3.01, *t*=32.68, $p<0.01$, Table 1) and AT3 (2.96, *t*=48.55, $p<0.01$, Table 1), higher than three in LH (3.33, *t*=33.23, $p<0.01$, Table 1). This showed that the growth pattern of goby varied with studied sites, ranging from negative allometry (in TT, DH and VH) to isometry (in TB and AT3) and positive allometry (in LH, Table 1). Table 2 displayed monthly variation in the growth pattern of this gobiid species. Only two months: February (*b*=3.25) and September (*b*=3.24) had positive allometry as *b* values were significantly higher than three (t_{Feb}=20.37, t_{Sep}=29.70, $p<0.01$, Table 2). From May to July plus October, the growth pattern was negative allometry due to *b* values were lower than threshold three (t-test, t_{May}=11.180, t_{Jun}=9.700, t_{July}=11.660, t_{Oct}=16.342, $p<0.01$, Table 2). The remaining months had isometry due to their *b* values were close to three (t-test, $p<0.01$ for all cases, Table 2).

Condition factor

The condition factor of *B. koilomatodon* expressed through *CF* value. Comparing to the standard parameter of one, the *CF* values did not vary by gender but changed with seasons and studied areas (Table 1). Specifically, condition factors of males and females were not different significantly at the level significance of 5% (t-test, *t*=0.31, $p>0.05$, Table 1). Meanwhile, this value showed the change between dry and wet seasons. The *CF* value of wet season (1.05) was higher than dry (0.98, t=3.80, $p<0.05$, Table 1). The condition factor of this goby (CF=0.85-1.16) changed with the studied site, reaching up the highest value in TT (1.16) (one-way ANOVA, *F*=13.50, $p<0.05$, Table 1). This value was independent of the interaction of gender × season (two-way ANOVA, *F*=0.29, $p>0.05$, Table 1) and gender × site (ANOVA, *F*=0.22, $p>0.05$, Table 1), but it was dependent on season × site interaction (ANOVA, *F*=5.84, $p<0.05$). The *CF* of this goby was approximated to one – the standard well-being parameter though this value changed with months (one-way ANOVA, *F*=3.18, $p<0.05$).

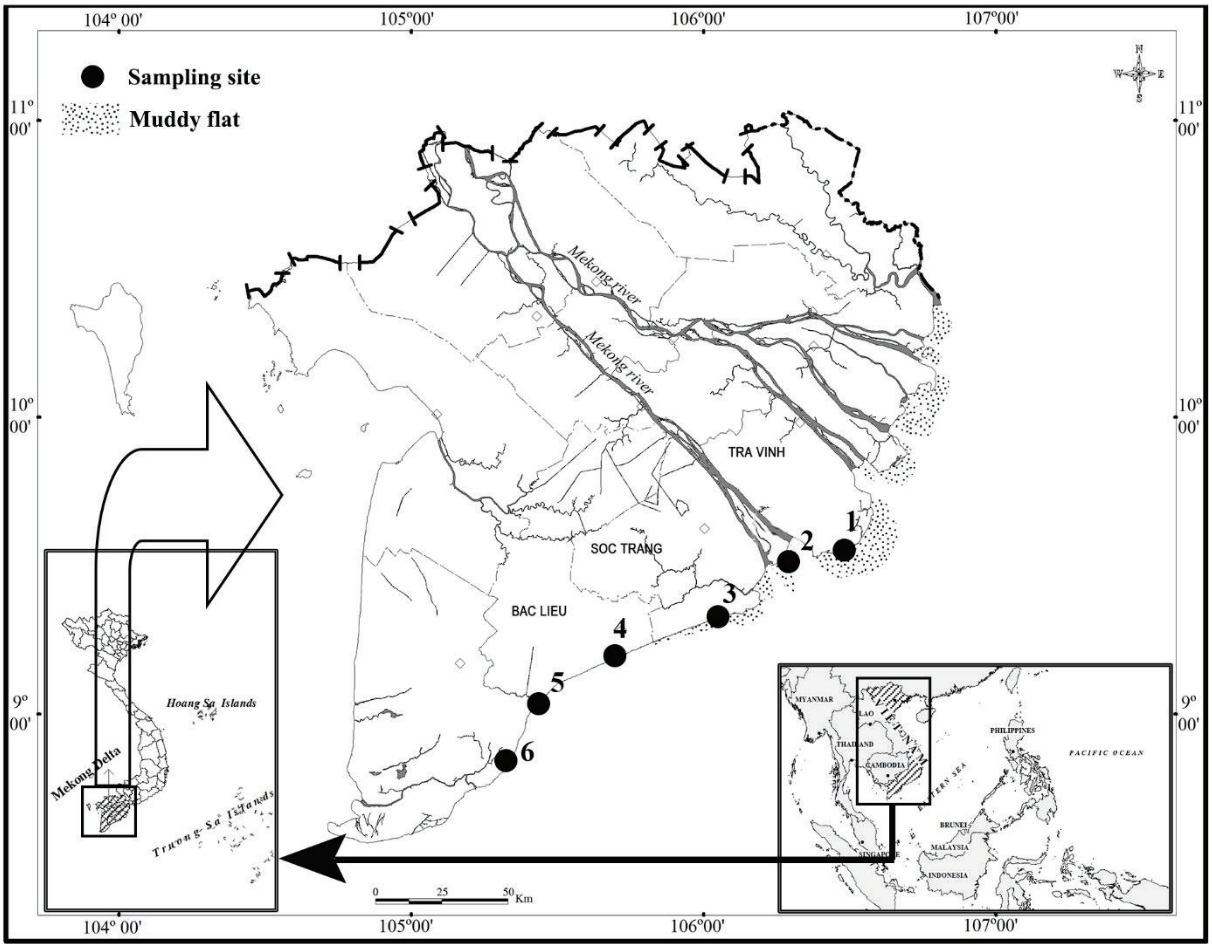

Fig. 1. The sampling map in the Mekong Delta (• Sampling areas: 1. Long Huu, Duyen Hai, Tra Vinh; 2. An Thanh 3, Cu Lao Dung, Soc Trang; 3. Trung Binh, Tran De, Soc Trang; 4. Vinh Hau, Hoa Binh, Bac Lieu; 5. Dien Hai, Dong Hai, Bac Lieu. 6. Tan Thuan, Dam Doi, Ca Mau.

Discussion

The results of this study demonstrate a significant difference in the weight and total length of *B. koilomatodon* between males and females (Table 1). Males are much longer and heavier than females. It indicates that the larger male is more successful in competing for nest sites. By selecting the best sites, they are better in maintaining the sites. If a male *Pomatoschistus minutus* fails to build a nest, it is replaced by another male (Lindström & Hellström 1993). Similarly, Houde (2001) has found that males of *Gobiusculus lavescens* are larger than females, competitively defending nest sites, courting females to attract them to the nest, and showing conspicuous breeding colouration. Hence, the body size may be the criterion for allowing active mate choice.

TLs and Ws are significantly greater in the dry season when compared to those in the wet season, which indicates that the seasonal change of environmental factors can influence body size of this fish. On the contrary, the morphologic traits of the goby *Parapocryptes serperaster* (see Dinh et al. 2016) and *Ilisha melastoma* (see Mahmood et al. 2012) in Pakistan showed no influence of seasons. Generally, the dry season is characterised by less rainfall than the wet season, plus the saline intrusion; thus, the salinity is higher during the dry period. Swennen et al. (1995) has stated that some gobies can survive in many types of water bodies with different salinity (up to 25‰) and a wide temperature range, from 28.7 to 36.8°C. Notably, *B. koilomatodon* is well adapted for growing in the dry environment.

The highest values of TLs and Ws are recorded in LH and VH while they were lowest in AT3 and VH. The reason for this may come from the difference of dominant vegetation. E. g., the flora in AT3 and VH comprises mainly *Avicennia marna* while *Bruguiera gymnorrhiza* and *Sonneratia caseolaris* are predominant in the flora of VH and LH. Thus, *B. koilomatodon* has a different adaptation depending on the interaction with the habitat. Considering the interactions of gender × season and gender × site, they do not cause changes on the growth of this fish species. Whereas the season × site interaction, the growth has been impacted. This shows the dependence on the type of habitats and wet-dry season pattern for *B.koilomatodon*.

Butis koilomatodon exhibits positive relationships between length and weight in gender, season and study areas. The connection suggests that the fish weight can be estimated from fish length despite the fish developmental stages. E.g., TLs reaches the highest value in LH and VH, so the highest Ws values are also recorded simultaneously. Similarly, other co-occurring gobies, e. g. *Pseudapocrytpes elongates* (see Tran 2008), *Boleophthalmus boddarti* (see Dinh 2014), *P. serperaster* (see Dinh et al. 2016), *Trypauchen vagina* (see Dinh 2016a), *Periophthalmodon schlosseri* (see Dinh 2016b) and *Oxyeleotris urophthlamus* (see Dinh 2016c) display positive relationships between length and weight. The results of Chukwu & Deekae (2011) on *Periophthalmus barbarus* and Panicker et al. (2013) on *Periophthalmus* has shown positive LWRs.

The slope values (*b* value) fluctuate from 1.89 to 3.33. This implies that the growth pattern is regulated by the months, seasons, sites and gender. E.g., in TT, *b* value (1.97) is lower than three, so the growth pattern is negative allometric growth. Conversely, this value is highest at LH Province (3.33), indicating positive allometric growth. The opposite outcomes are found in *P. barbarous* in Nigeria (King & Udo 1998); *P. serperaster* (see Dinh et al. 2016) and *T. vagina* (see Dinh 2016a) in the Mekong Delta, co-occurring with *B. koilomatodon* as they have adapted well to the environmental conditions. Particularly for *Stigmatogobius pleurostigma*, the *b* value is significantly lower than the isometric threshold (e.g., 3), suggesting this goby has a slimmer body shape (Dinh 2017). If *b* value is higher than the threshold of three (positive allometric growth), the fish would be plumped. Three is the desired value (isometric growth) because fish would have balanced growth.

Moreover, *b* values of *B.koilomatodon* are also affected by temperature and rainfall. Thus, the *b* value shows isometry in the dry season and negative allometry in the wet season. Hence, this species has adapted to dry season. The same result has been revealed in Table 2, in which growth pattern is mainly negative allometry during the rainy season (from April to October) but isometry and positive allometry during the dry season (from November to March). The studies by Tran (2008) on *P. elongatus*, Dinh et al. (2016) on *P. serperaster*, Dinh (2016a) on *T. vagina* in the Mekong Delta show these fishes could adapt well to their habitat and were not impacted by the environmental conditions, since the *b* values of these are a positive allometry during the dry and wet seasons. This goby displays different growth patterns implying that the growth pattern is greatly influenced by environmental conditions. Such as, *P. schlosseri* displays isometry in Malaysia (Khaironizam & Norma-Rashid 2002) and Vietnam (Dinh 2016b), yet negative allometry in Bangladesh (Saha 2013).

Our study shows that the condition factor of *B.koilomatodon* is not impacted by gender; however, they are dependent on the spatiotemporal factors such as season and locality. This suggests that the body conditioning of this goby cannot be related to the fish developmental stages. Likewise, the change of *CF* of *P. barbarus* is not affected by genders (King & Udo 1998, Chukwu & Deekae 2011). In contrast, *CF* has a powerful relationship with the fish developmental stage in the case of *P. serperaster* (see Dinh et al. 2016). The *CF* value of *B. koilomatodon* in the wet season is higher than in the dry season (Table 1), as it fluctuates around the threshold of one within twelve months (Table 2). This implies that *B.koilomatodon* can live in a favourable environment, which is also found for the gobiids *P. elongatus* (see Tran 2008), *P. serperaster* (see Dinh et al. 2016) and *T. vagina* (see Dinh 2016a).

Both factors, i.e. the studied regions and seasons, have influenced the growth of *B. koilomatodon.* Since the *b* values are higher than the isometric threshold of three and on the basis of the data in Table 1, *B. koilomatodon* in LH and TB is nutritionally favourable for growth. Two months, February and December, are the most suitable time for the development of this species (Table 2). The types of growth of *B. koilomatodon* do not change with gender. Similarly, the same outcomes have been found on *P. barbarus* (see King & Udo 1998, Chukwu & Deekae 2011), *P. serperaster* (see Dinh et al. 2016) and *T. vagina* (see Dinh 2016a). However, the interaction between seasons and sites has an impact on the value of *CF* of *B. koilomatodon*. This result shows a difference from those obtained by Dinh et al. (2016) for *P. serperaster*, which has been affected by the interaction of шге gender and the season in the Mekong Delta.

Conclusion

Butis koilomatodon exhibits positive relationship between TLs and Ws; thus, Ws can be inferred from TLs values. Factors such as gender, season, site and interaction between season and site affect length-weight relationship and growth pattern. The growth shows an isometric growth pattern in the dry season and sites in TB and AT3, and a positive allometric pattern in LH and TB. For the remaining cases, the growth shows negative allometric pattern. The temporal factor also affects the growth pattern, usually felling into isometric and positive allometric patterns in the months of the dry season. This species is well adapted to the dry season at the sites studied since the overall *CF* values are close to one.

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